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Gerontechnology ranking using the TOPSIS methods

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ABSTRACT

Population ageing is a major challenge affecting the future of science and technology policy and governance in industrialised societies. In this context, a key element is ensuring adequate protection, safety and care for older people when needed. The solution to enable active and healthy ageing is innovative technologies called gerontechnologies, which support older people. However, there is a knowledge gap regarding the systematic analysis and evaluation of gerontechnologies, which requires research in theoretical and empirical aspects. There is a need to focus on developing and supporting gerontechnologies to help older people reach their full potential in different spheres of life. Research should focus on analysing these technologies, their effectiveness and their impact on the quality of life of older people. This paper evaluates, analyses and builds a ranking of several selected technologies: (1) the wheelchair based on artificial intelligence Wheelie7, (2) the humanoid Rudy Robot, and (3) the wristband/watch VitalBand. The research was conducted in Poland. Based on a literature review, the authors identified relevant technologies to improve the quality of life of older people. These technologies were then assessed by people over 40 against various criteria. This age group was chosen because the issues of gerontechnology concern these people now in the context of their parents using the technology and being potential users of gerontechnology in 20–30 years. The study answered the following research questions: (1) What are the criteria for evaluating technologies that enhance the quality of life for older individuals? (2) How were the selected gerontechnologies evaluated? (3) How should the TOPSIS method be applied to build a ranking of gerontechnologies? (4) Which of the selected gerontechnologies was rated the highest by potential users?

KEY WORDS
technology management, gerontechnology, ranking, Multiple Criteria Group Decision Making, TOPSIS

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Introduction

The challenge for many developed countries in Europe and the world is the changing structure of society, in which older people constitute an increasing share (Eurostat, 2023). At the same time, the life model is changing, in which multi-generational family farms are replaced by single- or two-generation families, where an increasing share of time is devoted to the professional work of adults and learning (also in the form of additional activities) of children and adolescents. Consequently, caring for older people,

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which often requires constant attention for health reasons, becomes a significant problem (Scott et al., 2019).

In response to such challenges, retirement homes, also called senior, nursing or older people's homes, are becoming increasingly more important (Siefert & Schelling, 2018). Unfortunately, even though the number of such entities is systematically growing, the problem is to employ sufficient staff with appropriate qualifications to care for older adults. It should be emphasised that proper care for older adults includes aspects related to the implementation of typical life activities (meals, laundry, and taking medications) and social aspects, such as conversation, closeness, understanding, tenderness, etc.

Although comprehensive care for older adults can only be provided by other people, in the era of the development of information technologies and robotics, technological solutions to meet the challenges of caring for older adults, known as gerontechnology, are becoming increasingly important (Huang & Oteng, 2023).

Ageing populations around the world present unique challenges for older adult's care, health, and quality of life. As life expectancy increases, there is a growing need to develop innovative solutions to enable active and healthy ageing and improve quality of life in later years. Gerontechnology is one key area gaining increasing importance in the context of ageing. It is an interdisciplinary field combining technical, health and social sciences to create innovative technological solutions to support older people's daily lives. In today's digital age, technology can play a key role in increasing independence, improving health, and providing comfort for older people. Gerontechnology covers various technologies, from smart home devices and wearable gadgets to telemedicine systems and robotics. However, with many technologies available, the question arises: How should gerontechnologies be ranked and ordered?

This article focuses on the importance of gerontechnology ranking and methods for making such an assessment. Ranking gerontechnologies is an important tool that helps to identify the most effective and useful solutions adapted to the needs of older people. It covers various aspects of technological innovation, including health, social, economic, and technical aspects.

As technology develops at an alarming rate, the gerontechnology ranking becomes even more relevant. It allows for informed selection and investment in solutions that bring the greatest value to older people and ageing societies. However, developing effective gerontechnology ranking methods is challenging, given the variety of technologies available and their complexity.

This article discusses different approaches to ranking gerontechnologies, including methods for assessing effectiveness, indicators for evaluating quality of life and economic aspects of innovation. In addition, it identifies the key factors considered for ranking and discusses the challenges of evaluating technological solutions for older people.

Evaluating and ranking gerontechnology is a process that can help direct innovations so they would meet the real needs of older people and contribute to improving their quality of life. It is worth exploring this area to better understand how technology can support ageing societies.

This article presents the results of empirical research on the use of three technological solutions, i.e., (1) the wheelchair based on artificial intelligence Wheelie7, (2) the humanoid Rudy Robot, and (3) the wristband/watch VitalBand, for the support of care for older adults. The results of surveys conducted on a group of 1152 Polish residents over 40 were analysed.

The research conducted as part of the article aimed to find answers to the following research questions:

- What are the criteria for evaluating technologies that enhance the quality of life for older individuals?
- How were the selected gerontechnologies evaluated?
- How should the TOPSIS method be applied to build a ranking of gerontechnologies?
- Which of the selected gerontechnologies was rated the highest by potential users?

The article is divided into five parts. After the introduction, the first chapter reviews the literature and presents different authors' visions of gerontechnology. The second chapter presents the entire research procedure, techniques used in the research, sample distribution, etc. The next chapter describes research results, aiming to identify the most sought-after gerontechnologies in society and develop a ranking of selected gerontechnologies. The ranking was built using two TOPSIS methods. The article ended with research conclusions. The research techniques used in the study are CAWI (computer-assisted Internet interview) and the TOPSIS method.

1. Literature review

Due to current challenges in the field of care for older adults, gerontechnology is becoming the subject of many scientific studies. For the first time, the issue of gene technology was discussed in greater detail during the 1st International Congress on Gerontechnology, during which work results were presented by, among others, Bouma (1992), Vermijs and Vanbeurden (1992), Henny, Collins and Platts (1992) and Sixsmith and Sixsmith (1992). Since then, research has been conducted in many directions. Some researchers focused on identifying the causes of difficulties in adapting modern technologies supporting the functioning of older people (Chen & Chan, 2014; Gullà et al., 2015; Wu et al., 2015; Yusif et al., 2016; Bevilacqua et al., 2020). Other research efforts emphasise the importance of gerontechnology in the context of modern technologies that can be implemented to support older people and problems with employing staff for this type of work (Cook et al., 2020; Robinson et al., 2020). Many researchers also emphasise the importance of gerontechnology as an important tool to support older adults and care-providing employees and family members (McHugh & Lawlor, 2012; Hopwood et al., 2018).

A significant part of the research focused on aspects related to technologies used to care for older adults. According to published research results, one of the key motivations for accepting gerontechnology was the usefulness of the technology dedicated to this purpose. Numerous studies have demonstrated that older individuals utilise technology in various aspects of their lives, such as cooking, facilitating daily routines, communication, and entertainment. This has been highlighted in the research conducted by Delbreil and Zvobgo (2013), Portet et al. (2013), Menghi et al. (2017), and Huang et al. (2021). Likewise, several scholars have pointed out that the acceptance of gerontechnology significantly impacts the satisfaction of older people's personal needs across different life domains. Examples include Arthanat et al. (2019), Jarvis et al. (2020), and Reitsma et al. (2019). These studies reveal that older adults' technology adoption is driven by their desire for improved health, achievement, independence, and peace of mind.

Furthermore, research has indicated that older adults' attitudes towards technology use are influenced by their willingness to invest in technology, as demonstrated by Peek et al. (2016). Additionally, the frequency of technology use enhances communication with close and significant individuals, as observed by Ollevier et al. (2020). Beyond personal advantages, the value of gerontechnology is closely intertwined with its social benefits. Literature suggests that the perceived utility of gerontechnology can lead to the creation of new job opportunities and tangible improvements in overall quality of life, as Wilson et al. (2021) exemplified. It is also noteworthy that the perceived usefulness of gerontechnology has been acknowledged as a vital factor in enhancing the health and safety of older adults by individuals caring for them, as evident in the studies by Delbreil and Zvobgo (2013) and Cohen et al. (2016). In summary, it can be concluded that the perceived usefulness of gerontechnology can offer numerous personal and social benefits for older individuals and their family members and caregivers.

Graafmans et al. (1998) took a comprehensive look at the role of technology in improving the quality of life of older people. They discussed various gerontechnology aspects, including social, economic and health aspects. Kwon (2017) discussed current research and practice in technology and human ageing. He focused on technologies that support older adults' care and the design and evaluation aspects of such solutions. In contrast, Pak and Collins McLaughlin (2018) examined the impact of technology on the health and quality of life of older people. Various gerontechnology areas are discussed, such as telemedicine and smart homes. Issues related to telemedicine have been discussed by Wu et al. (2023). They present a remote CGA (Comprehensive Geriatric Assessment), which enables early disease detection, monitors chronic disease progression, provides personalised care, and optimises healthcare resources for better health outcomes in older people. In contrast, Maia et al. (2023) introduced an interactive technology to prevent falls in older adults. Forkan et al. (2023) delineated a personalised Internet of Things (IoT)-based Ambient Assisted Living (AAL) system designed to empower older individuals to lead independent and secure lives within the comfort of their homes. This system operates through real-time monitoring and intervention. The HalleyAssist system, leveraging smart home automation features, offers a novel approach for monitoring well-being and promptly identifying any abnormal changes in the behavioural patterns of older individuals. The innovative aspect of this approach lies in utilising machine learning models that autonomously learn an individual's typical behavioural patterns based on data from IoT sensors. These models are then harnessed to detect significant deviations in behavioural patterns when they occur. The paper presents the system's architecture and proof of concept and explores the measures taken to address privacy and security concerns. Additionally, the study includes the outcomes of a home trial conducted with an initial version of the system, during which it was deployed in the residences of four elderly participants for six weeks.

In contrast, the paper (Chaparro et al., 2023) proposes an architectural model for a mixed reality ecosystem to support the daily activities of older people. The paper recommends designing ecosystem elements that can be used in two scenarios to rehabilitate patients' visual-constructive abilities, creating a more appropriate and detailed connection and implementing connectivity, software and peripherals. In contrast, Chan et al. (2008) focused on smart homes as a key aspect of gerontechnology. They presented various technological solutions to support older people in their daily lives. In contrast, Asghar et al. (2017) focused on assistive technologies for the elderly and analysed trends in this field. In their study, Gasteiger et al. (2021) delved into the usability, acceptability, and perceptions of cognitive games delivered via a robot equipped with movable interactive blocks among older adults residing in the community. The findings underscored that cognitive games administered through a robot could supplement existing cognitive stimulation activities. Notably, the robot was deemed user-friendly and instrumental in enhancing cognitive functioning. On the other hand, Ejdys and Gulc (2022) aimed to identify the key determinants of the successful adoption of a specific gerontechnology in Poland. They focused on the Rudy Robot, an AI-powered mobile solution designed to support users in maintaining physical health, cognitive acuity, and social connections. The research confirmed that the Rudy Robot's functionality for the care of older adults positively impacted older individuals' willingness to embrace it for their own needs or those of their family members. The outcomes validated the utility of robots as assistive technology for older adults.

Unfortunately, despite the large number of studies published so far, very few are devoted to selecting the right technology for the needs of older people. This became the goal for the research work presented in this article.

2. Research methods

The entire research process consists of four main stages (Table 1). Based on a thorough literature review, the first stage identifies the technologies assessed in the following stages to build a ranking. Based on previous research by the authors, respondents believed that gerontechnologies addressing issues related to mobility, safety and health were the most important. Therefore, the selected technologies should belong to these groups. In addition, the technologies should be commercially available, easy to use and functional (Ejdys, 2018). Finally, three technologies were selected for further evaluation: the wheelchair based on artificial intelligence: Wheelie7 (GT1), Rudy Robot (GT2), and VitalBand (GT3). The VitalBand watch can measure, display, transmit and communicate information on heart rate, respiratory rate, blood pressure, number of steps, movement, and calories burned. It can be used to measure and manage information on an older person's fitness, vital signs and physical activity. The watch interface is adapted to the needs and capabilities of an older person. Connected to VitalCare, real-time vital signs data is collected via integrated medical devices. By creating a daily and historical awareness of physiological data, patients monitor themselves better and can quickly take self-care action. Patients are involved in their care plans, marking their medications as taken, missed or omitted, helping with adherence and improving the quality of care. With VitalCare Family, relatives can track whether a patient has taken medication,skipped a dose and/or read notes entered

Tab. 1. Research process for the construction of the ranking of selected gerontechnologies using the TOPSIS method

Stage number	Name of stage	Methods used
STAGE 1	Identification of gerontechnologies	Literature review
STAGE 2	Identification of evaluation criteria for selected gerontechnologies	Literature review
STAGE 3	Evaluation of gerontechnologies	CAWI survey
STAGE 4	Construction of the ranking	TOPSIS

by the patient or the doctor. Conversely, Wheelie7, the wheelchair driven by artificial intelligence, stands out as the planet's inaugural innovation, granting elderly individuals the ability to steer the wheelchair using only their facial expressions. The Wheelie7 system swiftly identifies the user's facial expressions and instantly interprets them to navigate the wheelchair's path. The ten gestures discerned by the Wheelie7 wheelchair prototype include smiling, raising eyebrows, and wrinkling the nose. The Rudy Robot accompanies an older person all day long. It helps with mobility and simple tasks and reminds the person to take medication. It is also a good companion for games and activities (Ejdys & Halicka, 2018).

In the second stage, 42 technology assessment criteria were selected based on the literature review. These criteria were sorted into seven groups: (1) Innovation (I1–I4); (2) Technology Demand (D1–D8); (3) Social–Ethical (SE1–SE6); (4) Ecological (E1–E8); (5) Ease of Use (EoU1–EoU4); (6) Functionality (F1–F5); and (7) User Attitude (UA1–UA7).

The third stage uses the criteria identified in stage two to evaluate the three selected technologies (Halicka & Surel, 2021). Respondents evaluated three technologies, i.e., VitalBand, Rudy Robot, and Wheelie7, using the 42 identified criteria. The study engaged individuals above the age of 40. The selection of participants within this age bracket stems from the relevance of gerontechnology matters to this demographic, considering their present involvement with such technology for their parents' care. Additionally, these individuals could become prospective users of gerontechnology in the upcoming 20–30 years. The survey was executed between December 2021 and January 2022, encompassing a representative cross-section of 1152 Polish citizens. A 7-point Likert scale was used, where 1 meant "I definitely disagree" and 7 — "I definitely agree". Along with the questionnaire, respondents were given information about the three technologies, their applicability, pictures, and links to websites.

In stage four, a gerontechnology (GT) ranking was constructed using the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method. This method was chosen arbitrarily. It is one of the most widely used methods and involves selecting the option with the smallest distance from the ideal solution and the largest distance from the least desirable solution (Behzadian et al., 2012). The TOPSIS method was first described by Hwang and Yoon in 1981 (Hwang & Yoon, 1981). The popularity

Yoon in 1981 (Hwang & Yoon, 1981). The popularity of the TOPSIS method is influenced by its simplicity and, more importantly, its adaptability to the input data (Kozlowska, 2022; Halicka & Kacprzak, 2021). The classical TOPSIS method uses two reference points, the first point being the so-called ideal solution and the second — negative ideal solution (Wieckowski & Salabun, 2020). The optimal solution should be closest to the ideal and be as far away from the negative ideal solution as possible (Ozkaya & Erdin, 2020). As the increasing complexity of the decision problems under analysis makes it less feasible for a single decision-maker to consider all relevant aspects of the problems, group decision-making is necessary. Let DM_k $(k = 1,2, \dots, K)$ be a group of decision-makers. Mathematically, the TOPSIS method for group decision-making with aggregation of individual decisions can be described in the following steps:

Step 1: Formulating the decision problem, i.e., defining what will be addressed next (Wartobski et al., 2020).

Step 2: Identifying, based on the formulated decision problem, a set of criteria C_j $(j = 1, 2, \dots, n)$ and the set of options to be selected GT_i $(i = 1, 2, \dots, m)$ (Varatharajulua et al., 2021).

Step 3: Breaking down criteria into stimulants $(C_j \in B)$ and destimulants $(C_j \in C)$.

Step 4: Determining the vector of criteria weights w_j $(j = 1, 2, \dots, n)$ corresponding to the individual criteria (Shekhovtsov & Kolodziejczyk, 2020).

Step 5: Calculating x_{ij}, i.e., evaluating the option GT_i in relation to the criterion C_j.

Step 6: Constructing the decision matrix X^k $(k = 1,2, \dots, K)$, assuming that each decision-maker DM_k has provided his/her decision matrix (individual decision) (Hasnain et al., 2019):

$$X^k = \left[x_{ij}^k\right]_{m \times n} = \begin{matrix} GT_1 \\ GT_2 \\ \vdots \\ GT_m \end{matrix} \begin{bmatrix} x_{11}^k & x_{12}^k & \cdots & x_{1n}^k \\ x_{21}^k & x_{22}^k & \cdots & x_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1}^k & x_{m2}^k & \cdots & x_{mn}^k \end{bmatrix} \quad (1)$$

Step 7: Normalising the decision matrix X^k $(k = 1,2, \dots, K)$ (Kacprzak, 2019):

$$R^k = \left[r_{ij}^k\right]_{m \times n} = \begin{matrix} DM_k \\ GT_1 \\ GT_2 \\ \vdots \\ GT_m \end{matrix} \begin{matrix} \begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{bmatrix} r_{11}^k & r_{12}^k & \cdots & r_{1n}^k \\ r_{21}^k & r_{22}^k & \cdots & r_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1}^k & r_{m2}^k & \cdots & r_{mn}^k \end{bmatrix} \end{matrix} \quad (2)$$

where:

$$r^k{}_{ij} = \frac{x^k{}_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}. \quad (3)$$

Step 8: Using a vector of weights $w = (w_1, w_2, \dots, w_n)$ to determine the weighted normalised decision matrix V^k for each criterion DM_k $(k = 1,2, \dots, K)$:

$$V^k = [v_{ij}^k]_{m\times n} = \begin{array}{c} DM_k \\ GT_1 \\ GT_2 \\ \vdots \\ GT_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} v_{11}^k & v_{12}^k & \cdots & v_{1n}^k \\ v_{21}^k & v_{22}^k & \cdots & v_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ v_{m1}^k & v_{m2}^k & \cdots & v_{mn}^k \end{bmatrix} \end{array} \quad (4)$$

where:

$$v_{ij}^k = r_{ij}^k \cdot w_j$$

Step 9: Calculating the aggregate weighted normalised decision matrix for group decision-making.

One of the most popular and widely used group decision-making methods is the aggregation of individual standardised matrices V^k $(k = 1,2, \dots, K)$ into an aggregated collective matrix V according to the formula:

$$V = [v_{ij}]_{m\times n} = \begin{array}{c} \\ GT_1 \\ GT_2 \\ \vdots \\ GT_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix} \end{array} \quad (5)$$

The most common aggregation methods are:

ART — arithmetic mean (Wang & Chang, 2007):

$$v_{ij} = \frac{1}{K} \sum_{k=1}^{K} v_{ij}^k, \quad (6)$$

GEO — geometric mean (Ye & Li, 2009):

$$v_{ij} = \left(\prod_{k=1}^{K} v_{ij}^k\right)^{\frac{1}{K}}. \quad (7)$$

Step 10: Determining coordinates of the ideal solution (pattern) A^+ and the negative ideal solution A^- (Pawanr et al., 2019).

The ideal solution has the form:

$$A^+ = \{v_1^+, v_2^+, \dots, v_n^+\}, \quad (8)$$

where:

$$v_j^+ = \{max_i v_{ij}, j \in B \;\; min_i v_{ij}, j \in C\}; \quad (9)$$

a negative ideal:

$$A^- = \{v_1^-, v_2^-, \dots, v_n^-\}, \quad (10)$$

where

$$v_j^- = \{min_i v_{ij}, j \in B \;\; max_i v_{ij}, j \in C\}. \quad (11)$$

Step 11: Determining the distance of the considered options from the ideal solution d_i^+ (Nowak et al., 2020):

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \quad (12)$$

and a negative ideal solution d_i^- (Nowak et al., 2020):

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}. \quad (13)$$

Step 12: Determining the coefficients RC_i determining the relative proximity of the decision options to the ideal solution (Kacprzak, 2020; Yue, 2014):

$$RC_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad (14)$$

where $RC_i \in [0; 1]$

Step 13: Building a final ranking of the decision options due to the value of RC_i. The ranking is built from the largest coefficient value to the smallest (Ezhilarasan & Vijayalakshmi, 2020). This means that the most favourable decision options are those with the highest values of the relative proximity coefficient.

The described algorithm allows for the selection of a leader when the input is real numbers. The following subsection will describe the case of the TOPSIS method, which is used to identify the leader when interval numbers are given.

3. Research results

The research aimed to build a ranking of selected gerontechnologies $\{GT_1, GT2_2, \mathrm{GT}_3\}$. These technologies are evaluated by a group of 1152 decision-makers, i.e., $\{DM_1, DM_2, \dots, DM_{1152}\}$. Each decision-maker rated each technology against 42 criteria, using the following point scale: $\{1,2, \dots ,7\}$.

The classic TOPSIS method was applied to the pooled matrix after aggregating the individual matrices provided by the DM using the arithmetic mean — TOPSIS_ART and the geometric mean — TOPSIS_GEO.

According to the presented test methodology, a vector of criteria was determined. The criteria weights were determined using the entropy method (Halicka & Kacprzak, 2021; Lotfi & Fallahnejad, 2010). The vector of weights for aggregation using the arithmetic mean is shown in Table 2, and for aggregation using the geometric mean in Table 3.

According to formulas 5, 6 and 7, a weighted normalised decision matrix V_ART and V_GEO was determined (Tables 4 and 5).

Then, formulas 8, 9, 10 and 11 were used to determine the coordinates of the ideal solution (pattern), A^{+} and negative ideal (anti-pattern) A^{-}, for aggregation using the arithmetic mean (Table 6) and the geometric mean (Table 7).

Then, formulas 12, 13 and 14 were used to determine the distances of the variants under consideration from the ideal and negative ideal solutions, d_i^{+} and negative ideal solution d_i^{-} , and the final ranking of the variants (R) of the decision-making variants due to the value of the coefficient RC_i for aggregation using the arithmetic mean and geometric mean method. These values are shown in Table 8.

It should be observed that the ultimate outcomes achieved for TOPSIS_ART and TOPSIS_GEO display slight discrepancies due to distinct methods of aggregation. Nevertheless, despite the variance in aggregation techniques, both TOPSIS_ART and TOPSIS_GEO yield identical rankings for gerontechnologies when considering the formula (the symbol $\prec$ indicates worse than): $GT_2 \prec GT_3 \prec GT_1$.

In both cases, Wheelie7 was rated the highest. This technology is ranked first. Rudy Robot received the lowest rating.

Tab. 2. Weights of objective criteria determined by the entropy method for aggregation using the arithmetic mean

	I1	I2	I3	I4	D1	D2	D3	D4	D5	D6	D7	D8	SE1	SE2
w_i	0.031	0.051	0.045	0.048	0.043	0.048	0.044	0.020	0.014	0.042	0.040	0.011	0.014	0.017
	SE3	**SE4**	**SE5**	**SE6**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**EoU1**	**EoU2**
w_i	0.023	0.005	0.003	0.008	0.029	0.012	0.005	0.006	0.001	0.006	0.006	0.006	0.009	0.030
	EoU3	**EoU4**	**F1**	**F2**	**F3**	**F4**	**F5**	**UA1**	**UA2**	**UA3**	**UA4**	**UA5**	**UA6**	**UA7**
w_i	0.005	0.038	0.051	0.049	0.041	0.032	0.003	0.025	0.019	0.028	0.015	0.023	0.024	0.030

Tab. 3. Weights of objective criteria determined by the entropy method for aggregation using the geometric mean

	I1	I2	I3	I4	D1	D2	D3	D4	D5	D6	D7	D8	SE1	SE2
w_i	0.030	0.045	0.044	0.049	0.047	0.046	0.042	0.024	0.017	0.018	0.021	0.013	0.019	0.018
	SE3	**SE4**	**SE5**	**SE6**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**EoU1**	**EoU2**
w_i	0.026	0.003	0.002	0.007	0.023	0.009	0.003	0.004	0.000	0.005	0.005	0.007	0.007	0.036
	EoU3	**EoU4**	**F1**	**F2**	**F3**	**F4**	**F5**	**UA1**	**UA2**	**UA3**	**UA4**	**UA5**	**UA6**	**UA7**
w_i	0.003	0.051	0.050	0.050	0.043	0.036	0.003	0.031	0.025	0.032	0.018	0.027	0.028	0.033

Tab. 4. Weighted normalised decision matrix V_ART (aggregation using arithmetic mean)

	I1	I2	I3	I4	D1	D2	D3	D4	D5	D6	D7	D8	SE1	SE2
T1	0.019	0.031	0.028	0.030	0.026	0.030	0.027	0.011	0.008	0.023	0.022	0.006	0.009	0.010
T2	0.017	0.028	0.025	0.027	0.023	0.026	0.024	0.011	0.008	0.023	0.023	0.006	0.008	0.009
T3	0.018	0.028	0.026	0.026	0.025	0.027	0.025	0.012	0.008	0.026	0.025	0.006	0.008	0.010
	SE3	**SE4**	**SE5**	**SE6**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**EoU1**	**EoU2**
T1	0.014	0.003	0.002	0.005	0.018	0.007	0.003	0.003	0.001	0.003	0.003	0.004	0.005	0.018
T2	0.013	0.003	0.002	0.005	0.016	0.007	0.003	0.003	0.001	0.003	0.003	0.004	0.005	0.017
T3	0.013	0.003	0.002	0.005	0.016	0.007	0.003	0.003	0.001	0.003	0.003	0.004	0.005	0.016
	EoU3	**EoU4**	**F1**	**F2**	**F3**	**F4**	**F5**	**UA1**	**UA2**	**UA3**	**UA4**	**UA5**	**UA6**	**UA7**
T1	0.003	0.023	0.032	0.030	0.025	0.019	0.002	0.015	0.011	0.017	0.009	0.014	0.014	0.018
T2	0.003	0.023	0.028	0.027	0.023	0.018	0.002	0.014	0.010	0.015	0.008	0.013	0.013	0.017
T3	0.003	0.021	0.030	0.028	0.023	0.018	0.002	0.014	0.011	0.016	0.009	0.013	0.014	0.018

Tab. 5. Weighted normalised decision matrix V_GEO (aggregation using geometric mean)

	I1	**I2**	**I3**	**I4**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**SE1**	**SE2**
T1	0.019	0.029	0.027	0.031	0.029	0.029	0.027	0.014	0.010	0.010	0.011	0.008	0.012	0.011
T2	0.016	0.024	0.023	0.027	0.025	0.025	0.023	0.013	0.009	0.010	0.012	0.007	0.010	0.010
T3	0.017	0.025	0.025	0.027	0.027	0.026	0.024	0.015	0.010	0.011	0.013	0.007	0.011	0.010
	SE3	**SE4**	**SE5**	**SE6**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**EoU1**	**EoU2**
T1	0.016	0.002	0.001	0.004	0.014	0.006	0.002	0.002	0.000	0.003	0.003	0.004	0.004	0.022
T2	0.014	0.002	0.001	0.004	0.013	0.005	0.002	0.002	0.000	0.003	0.003	0.004	0.004	0.021
T3	0.015	0.002	0.001	0.004	0.013	0.005	0.002	0.002	0.000	0.003	0.003	0.004	0.004	0.019
	EoU3	**EoU4**	**F1**	**F2**	**F3**	**F4**	**F5**	**UA1**	**UA2**	**UA3**	**UA4**	**UA5**	**UA6**	**UA7**
T1	0.002	0.031	0.032	0.032	0.027	0.022	0.001	0.019	0.015	0.020	0.011	0.016	0.017	0.020
T2	0.002	0.030	0.027	0.027	0.023	0.019	0.001	0.017	0.014	0.017	0.010	0.014	0.015	0.018
T3	0.002	0.026	0.029	0.028	0.023	0.020	0.001	0.018	0.014	0.018	0.010	0.015	0.016	0.020

Tab. 6. Coordinates of ideal and negative ideal solution for aggregation using arithmetic mean

	I1	**I2**	**I3**	**I4**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**SE1**	**SE2**
A^+	0.019	0.031	0.028	0.030	0.026	0.030	0.027	0.012	0.008	0.026	0.025	0.006	0.009	0.010
A^-	0.017	0.028	0.025	0.026	0.023	0.026	0.024	0.011	0.008	0.023	0.022	0.006	0.008	0.009
	SE3	**SE4**	**SE5**	**SE6**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**EoU1**	**EoU2**
A^+	0.014	0.003	0.002	0.005	0.018	0.007	0.003	0.003	0.001	0.003	0.003	0.004	0.005	0.018
A^-	0.013	0.003	0.002	0.005	0.016	0.007	0.003	0.003	0.001	0.003	0.003	0.004	0.005	0.016
	EoU3	**EoU4**	**F1**	**F2**	**F3**	**F4**	**F5**	**UA1**	**UA2**	**UA3**	**UA4**	**UA5**	**UA6**	**UA7**
A^+	0.003	0.023	0.032	0.030	0.025	0.019	0.002	0.015	0.011	0.017	0.009	0.014	0.014	0.018
A^-	0.003	0.021	0.028	0.027	0.023	0.018	0.002	0.014	0.010	0.015	0.008	0.013	0.013	0.017

Tab. 7. Coordinates of the ideal and negative ideal solution for aggregation using geometric mean

	I1	**I2**	**I3**	**I4**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**SE1**	**SE2**
A^+	0.019	0.029	0.027	0.031	0.029	0.029	0.027	0.015	0.010	0.011	0.013	0.008	0.012	0.011
A^-	0.016	0.024	0.023	0.027	0.025	0.025	0.023	0.013	0.009	0.010	0.011	0.007	0.010	0.010
	SE3	**SE4**	**SE5**	**SE6**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**EoU1**	**EoU2**
A^+	0.016	0.002	0.001	0.004	0.014	0.006	0.002	0.002	0.000	0.003	0.003	0.004	0.004	0.022
A^-	0.014	0.002	0.001	0.004	0.013	0.005	0.002	0.002	0.000	0.003	0.003	0.004	0.004	0.019
	EoU3	**EoU4**	**F1**	**F2**	**F3**	**F4**	**F5**	**UA1**	**UA2**	**UA3**	**UA4**	**UA5**	**UA6**	**UA7**
A^+	0.002	0.031	0.032	0.032	0.027	0.022	0.001	0.019	0.015	0.020	0.011	0.016	0.017	0.020
A^-	0.002	0.026	0.027	0.027	0.023	0.019	0.001	0.017	0.014	0.017	0.010	0.014	0.015	0.018

Tab. 8. Gerontechnology rankings using TOPSIS_ART and TOPSIS_GEO

Gerontechnology	**TOPSIS_ART**				**TOPSIS_GEO**			
	d_i^+	d_i^-	$\boldsymbol{RC_i}$	$\boldsymbol{R}$	d_i^+	d_i^-	$\boldsymbol{RC_i}$	$\boldsymbol{R}$
GT1 (Wheelie7)	0.004	0.012	0.746	1	0.002	0.016	0.896	1
GT2 (Rudy Robot)	0.011	0.003	0.193	3	0.015	0.004	0.228	3
GT3 (VitalBand)	0.009	0.006	0.397	2	0.012	0.006	0.342	2

Discussion and conclusions

The study featured in this article constitutes original research, with its principal objective centred on acquiring novel insights into discerning the requisites and anticipations of present and future technology users. The overarching goal is to enhance the quality of life for older adults in Poland by better understanding their needs and preferences.

In their daily lives, older people experience difficulties related to their deteriorating health. Gerontechnology addresses older people's problems and improves their quality of life. Based on this article, such technology enhances the well-being of older individuals by easing their reach to various commodities, services, and infrastructure. The multifaceted spectrum of needs and anticipations within the older demographic, coupled with various technologies sporting many different functionalities, necessitates a comprehensive perspective on gerontechnology matters. This entails pinpointing the clusters of technologies that can effectively address distinct categories of user requirements. One of the objectives of this paper is to evaluate and select three gerontechnologies that address such issues. Based on a thorough literature review, the authors have tentatively identified three gerontechnologies helpful for older people: the wheelchair based on artificial intelligence Wheelie7 (GT1), Rudy Robot (GT2), and VitalBand (GT3). These technologies were assessed against 42 criteria: four were related to innovation, four were related to ease of use, five included functionality, six were related to socio-ethical aspects, seven were from the user attitude group, and the technology demand and ecological groups had eight criteria each. Technologies were assessed by people aged 40 and over. This age group was chosen deliberately due to respondents having older parents who can use the technologies and also being potential users of gerontechnology in 20–30 years.

The next research stage was to develop a ranking of gerontechnologies to identify the technologies most highly rated by respondents, i.e., meeting their needs and expectations. The TOPSIS method was used to build the ranking. This method consists of selecting the variant with the smallest distance from the ideal variant and the largest distance from the least desirable variant. The survey involved 1152 respondents. Thus, the three selected technologies were evaluated by 1152 decision-makers. It was necessary to aggregate the individual decisions. The arithmetic means and geometric mean method was used for aggregation. In the end, two rankings, TOPSIS_ART and TOPSIS_GEO, were obtained. However, regardless of the aggregation method, the same ranking of the gerontechnologies was obtained. Wheelie7 was ranked the highest. Other studies (Abdi et al., 2021; Astasio-Picado et al., 2022) also concluded that devices using artificial intelligence will become increasingly more important in the care and support of older people in the near future.

In future studies, the authors intend to consider the opinions of decision-makers on the substance of the criteria when creating the ranking. They also plan to extend the research to other technologies. They also intend to conduct research in other European countries. In addition, they intend to expand the catalogue of criteria and develop the rankings using different methods. They also plan to use other data formats, such as fuzzy numbers, interval numbers, etc., to evaluate technologies. The authors hope that these steps will allow for a more comprehensive and holistic understanding of the assessment of gerontechnologies and their position in the market.

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